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Towards fuzzy preference relationship based on decision making approach to access the performance of suppliers in environmental conscious manufacturing domain

Amit Kumar Sinha *, Ankush Anand

Department of Mechanical Engineering, Shri Mata Vaishno Devi University, Katra, Jammu and Kashmir - 182320, India

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ABSTRACT

Environmental consciousness has become a significant aspect at various levels of product design. In the recent years, by and large industries are focusing towards environment conscious products. Quantitative analysis of energy consumption and waste generation from any product is directly related to the supply chain management of the product. Hence, the selection of most suitable supplier from the pool of available suppliers is emerged as an important multi attribute (multi objective, multi criteria, multi factor) decision making (MADM) problem. This research paper addresses the supplier selection problem from the perspective of supply analysis, logistic analysis, process analysis, use analysis and, recycle analysis for calculating environmental impact of a product. Based on the associated environmental importance of a product a procedure based on fuzzy framework is used for ranking and selecting the best suitable supplier from its environmental perspective. A multi preference fuzzy relationship model is introduced to incorporate the uncertainty in the decision making by the decision maker. Finally, a solution procedure based on OWA (Ordered Weighted Averaging) aggregation operator is developed. The proposed methodology has been discussed along with an illustrative examples.

1. Introduction

In the last few decades, environmental problems have gained increased attention of government, non-government organizations, customers, institutions, researchers and practitioners (McAleer, McIvor, Humphreys, & McCurry, 2000). Protection of the environment has become an important issue at all levels of society. Nowadays, the focus of environment protection strategy has been shifting from various components of earth (air, water, soil) to issues like acid rain, climate change, etc. (Smith et al., 2013). For example, Netherland which is suffering from a lot of environmental problems which include change in climate, depletion of ozone layer, dispersion of toxic substances, disposal of solid waste and, eutrophication (Ketting, 2011).

Pollution is nothing more than a form of waste. Under 1976 Resource Conservation and Recovery Act (RCRA), the US Environmental Protection Agency (USEPA) has estimated about 8 billion tons of industrial waste per annum. However, the most interesting fact during this study was that more than 214 million tons of wastes are hazardous in nature (Mike Ewall, 2007). This alarming amount of waste is generated at every stage of the production process, consumption and disposal of manufactured products. In the recent years, most of the industries are inching towards manufacturing environmental friendly products (Mike Ewall, 2007).

To respond for the environmental consciousness product, manufacturing companies have carried out a vast number of environmental programs. Great efforts have recently resulted in increasing the environmental performance of industrial products (Bovea & Wang, 2003). Environmental consciousness/friendliness is one of the most important criteria apart from quality, cost and, time-to-market for assessing the performance of suppliers (Agarwal & Vijayvargy, 2012). General Motors has launched a special drive coined as "WE CARE" (Waste Elimination and Cost Awareness Reward Everyone) which involves cooperation with suppliers on specific measures like reduction in waste of packaging material and, increase in their recycling ability (Barry, Girard, & Perras, 1993). Noci (1997) categories these environmental programs into three main phases: First phase was till 1970 where purchasing managers (decision makers) introduced the concept of end-of-pipe programs so that the air emission, solid wastes, waste water and energy consumption of the plant can be reduced. Time period of second phase is in between 1970 and 1980s. During second phase, the purchasing managers introduced the concept of

* Corresponding author.
E-mail address: amitsinha5050@gmail.com (A.K. Sinha).

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clean technologies programs aimed at reducing the company's impact on the state of natural resources by changing major steps in the production process. Third phase started from the beginning of 1990s where the purchasing managers changed the operating procedures and introduced the concept of eco-auditing framework.

Nowadays, it is a time of fourth phase according to which environmental consciousness manufacturing companies are developing eco-friendly programs aimed at organizing their supply value chains according to eco-efficiency perspective (Hass, 1996; Noci, 1995, 1997). Prior to 1980, the purchasing function was typically viewed as being primarily clerical, but today more analytics are employed to assess the environmental impact while addressing purchasing issues (Gupta, 1995). Therefore, purchasing manager must procure goods and services from that supplier(s), which are able to manufacture the products at the lowest cost, highest quality, shortest lead-time and greater flexibility and with minimum environmental impact (Dobos & Vörösmarty, 2014; Wetzstein, Hartmann, Benton, & Hohenstein, 2016).

Recent literatures (Awasthi, Chauhan, & Goyal, 2010; Gupta, 1995; Sarkis, 2003) on supplier selection address two important questions: (1) How to spot the preferred solution(s) based on environmental and business concerns? (2) How to improve the understanding of the trade-offs between these two dimensions? Literature survey reveals that there is a dearth of multi criteria and multi attribute decision making problem in the perspective of environmental conscious supplier selection domain (Genovese, Lenny Koh, Bruno, & Esposito, 2013; Jabbour & Jabbour, 2009). Although, many researchers (Bhattacharya et al., 2014; Humphreys, McCloskey, McIvor, Maguire, & Glackin, 2006) incorporated environmental consciousness issues into supply chain management. However, what is missing is an overall view of the overall environmental impact of any product in a whole supply chain so that any decision maker can take action to select those suppliers who has less overall environmental impact in whole supply chain management (Igarashi, de Boer, & Fet, 2013). In addition, most of the early literatures lack in exploring the broad environmental criteria either quantitatively or qualitatively with specific references to environmental cost coupled with production process, product and, management systems (Appolloni, Sun, Jia, & Li, 2014).

Handfield, Walton, Sroufe, and Melnyk (2002) suggested an AHP model for assessing and selecting environmentally conscious supplier. This model has however certain issues which needs further research in terms of critical weights, inappropriateness of the crisp ratio representation, rank reversal problem and, the difficulty in the comparing many criteria. Evaluation of supplier performance on the basis of environmental consideration is a complex problem. The complexity of such problems is characterized by the difficulty of finding a unique quantitative measure. It is an uphill task to compare the environmental damage parameters including, cost to hazardous impact, etc.

The decision-making problem handles the uncertainty which account for determining the relative importance of each criterion and their sub-criteria. Sometimes, decision-making problem becomes more critical when the available information is incomplete, imprecise or vague in nature. Apart from these things, decision makers have to handle both qualitative and quantitative criteria for evaluating the performance of environmental conscious supplier. This motivates the authors to propose a novel approach to solve a complex multi criteria decision making problem for a supply chain to assess the performance of suppliers in environmentally conscious manufacturing domain.

This research paper altogether presents a new paradigm shift in research area by two ways. In the first way, the authors have incorporated environmental criteria as a key factor for supplier selection at each stage of supply chain. We have introduced five analyses namely supply analysis, logistic analysis, process analysis, use analysis and recycle analysis and for each and every analysis we have calculated six different types of environmental impact for a product on the basis of global warming potential, ozone depletion potential, photochemical ozone creation potential, acidific potential, nutrient enrichment potential and, volatile organic compound potential.

In this paper, we propose a novel approach called multi preference fuzzy relationship based multi-criteria decision making ($MPFR_{MCDM}$) model for assessing the performance of suppliers in environmental conscious manufacturing domain. The aim of the paper is to develop a decision-making support tool for sustainable supplier selection under the domain of manufacturing industries. Framework of environmental conscious or sustainable supplier selection is another salient feature of this paper. An illustrative example is used to illustrate how the fuzzy preference relationship has been implemented. A sensitivity analysis is conducted to evaluate the influence of criteria weights on the environmental performance evaluation of suppliers.

The framework of the proposed $MPFR_{MCDM}$ approach encompasses various established decision making techniques to make the overall approach competitive and compatible with the problem at hand. Moreover, the $MPFR_{MCDM}$ uses an external repository concept to preserve all effective set of suppliers. $MPFR_{MCDM}$ approach incorporates a fuzzy based feedback mechanism which iteratively uses the information to determine the compromise solution. Finally, this paper has been structured with the following objectives:

(1) To validate the efficacy and application of the proposed model on complex multi criteria decision making problem for assessing the performance of suppliers in environmental conscious manufacturing domain.
(2) To solve highly constrained multi criteria decision making problem and obtain manageable and compromise solution.
(3) To present fuzzy preference relationship that has been applied to even out the data so as to emulate the human reasoning process and making decision based on vague and imprecise data.
(4) To eliminate the human effects in decision making process.

Therefore, the present paper attempts to select a most suitable supplier in the fuzzy framework of multi-criteria decision-making (MCDM) process, which has the least total environmental impact. A multi preference fuzzy relationship model has been adopted here for selecting the best supplier. The reason for using fuzzy relationship in the subjective evaluation is to incorporate the uncertainty in the decision by a particular decision maker.

Akin to AHP, we have modeled the problem of environmental conscious supplier selection in a hierarchy order. The decision maker has opined himself in multi-criteria fuzzy preference relationship. Next, on the basis of global information about the alternative we prepare a list of alternatives rank wise, from which the set of solution alternative is obtained. The OWA operator (Yager, 1988) has been utilized to calculate the global ranking of suppliers. This paper investigates the feasibility of applying a multi criteria fuzzy preference relation model in an environmental conscious supplier selection environment.

The rest of the paper is arranged as follows. In the next section, the literature review on decision making model for assessing the performance of suppliers in environmental conscious manufacturing domain is reviewed. Section 3 details the proposed approach for development of an environmental conscious supplier selection system. This section also deals with four levels of environmental emission hierarchy framework for the selection of supplier. In Section 4, a background of O.W.A operator and fuzzy multiplicative preference relationship is shown. In Section 5, we propose an